The process of stereoscopic perception: A magnetoencephalographic study

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1 Introduction

Binocular disparity is one of many clues to perceive depth. Random-dot stereograms (RDS) designed by Julesz [1] enables us to make visual stimuli that exclusively have binocular disparity as a depth clue. Many physiological studies were done about visual cortical neurons which respond to binocular disparity [2], but it is still not clear what large-scale activity of such neurons detects correspondent regions in both retinae and calculates amounts of disparity, which is considered to be necessary to perceive stereoscopic image. This study investigated magnetic fields evoked by visual stimuli including binocular disparities to elucidate macroscopic responses of visual cortical neurons in the process of stereoscopic perception.

2 Methods

The brain magnetic fields were recorded by a 64-channel whole cortex MEG system (NeuroSQUID Model-100, CTF Systems, Canada). The sampling rate of data acquisition was 625 Hz, and acquired data were filtered by a 40-Hz low-pass filter and a 1-Hz high-pass filter.

Visual stimuli used in this study were random-dot pattern reversals (RPR), correlated random-dot stereograms (C-RDS), and anticorrelated random-dot stereograms (A-RDS). RPR were used for detecting cortical activity evoked by local luminance changes. Although both C-RDS and A-RDS contained similar binocular disparities, subjects perceive stereoscopic images only in the case of C-RDS because the contrast of the patterns of the correspondent regions for one eye were reversed in A-RDS [3]. Examples of C-RDS and A-RDS are shown in Figure 1. The stimuli were generated by a video adapter on PC, and were displayed as anaglyphs on an LCD projector (DLA-G10, JVC, Japan). The subject-screen distance was 140 cm. Figure 2 shows stimulus positions in visual fields. Subjects were five healthy adult volunteers with normal or corrected-to-normal vision.

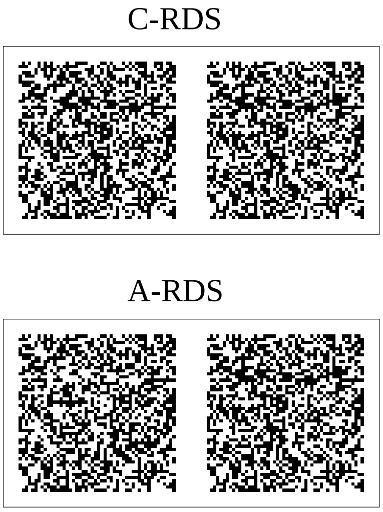

Figure 1: *Example stereograms. A floating square can be perceived by fusing upper two images (C-RDS) in crossed viewing. In fusing lower two images (A-RDS), the shape of the region with disparity can be seen, but no stable stereoscopic perception occurs.*

C-RDS and A-RDS were displayed both statically and dynamically. In the static display, images displayed to a subject changed only at a stimulus onset. On the contrary in the dynamic display, displayed images changed at every frame (60Hz) but the disparity condition changed only at a stimulus onset to reduce cortical responses related to local luminance changes. The subject fixated a cross-shaped fixation mark in the center of the screen. The stimulus duration was 733 ms and inter-stimulus intervals were ranging from 1 s to 3 s. Correlograms (CRG) were displayed during inter-stimulus intervals.

3 Results

3.1 Evoked magnetic fields

Interindividual differences existed in terms of latency and amplitude. Figure 6 shows representative results for two subjects YO and TO. Responses considered to

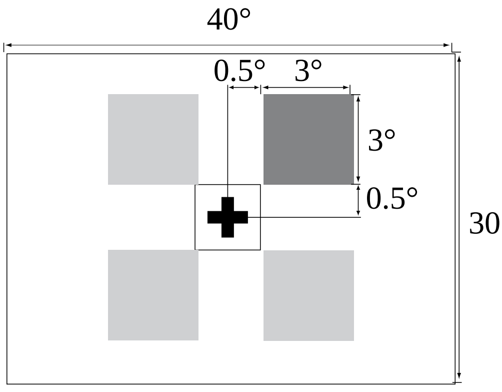

Figure 2: *Schematic illustration of visual stimuli. The length in the figure is given as the angle it subtends. The cross-shaped marker at the center of the figure is a fixation point. The four shadowed squares indicate the shapes and the positions of floating regions perceived by subjects. Only one floating square was displayed at one trial.*

be P100ms were observed in responses to RPR, static C-RDS and static A-RDS in subject TO, but there was no obvious P100m in subject YO.

3.2 Comparison between responses to dynamic C-RDS and dynamic A-RDS

Most subjects showed prominent responses to dynamic C-RDS, but did not show any obvious responses to dynamic A-RDS. To confirm this quantitatively, ratios of the time integral from the latency 100 ms to 400 ms of root-mean-square (RMS) values of responses to C-RDS to those to A-RDS were calcurated. Figure 3 shows the result.

3.3 Source localization

Most of all isocontour maps of measured responses did not show magnetic fields distribution considered to be a single dipole source.

Figure 4 shows two isocontour maps for the latency of 195 ms and 250 ms in responses evoked by dynamic C-RDS in subject YO. Both responses to static C-RDS and dynamic C-RDS exclusively have the similar second peak indicated by the right side of Figure 4, therefore it is considered to be specific to depth perception. The estimated source of the second peak was shown in Figure 5.

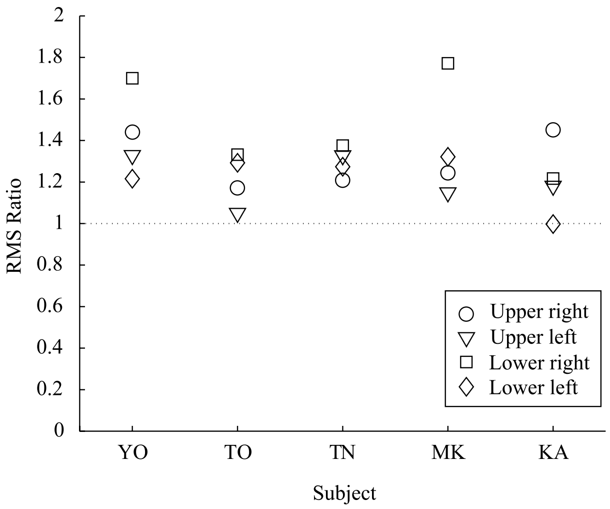

Figure 3: *Ratios of the time integral from the latency 100 ms to 400 ms of RMS values of responses to C-RDS to those to A-RDS. The shapes of points represents retinal stimulus locations.*

4 Discussion

Most of the peak components evoked by dynamic C-RDS were not seen in the responses to dynamic A-RDS, but disparity-sensitive neurons respond to both dynamic C-RDS and dynamic A-RDS [4]. Threfore the responses to dynamic C-RDS should be mainly due to higher cortical activity required to perceive depth, not a detection of local disparity. However, it should be considered that those responses to dynamic C-RDS and dynamic A-RDS derived by neurophysiological analysis were not completely the same.

The peak component considered to be specific to stereoscopic perception was localized around the parieto-occipital sulcus, which supports that the processing related to space recognition is done on a dorsal pathway of visual information processing.

Some EEG studies suggests stimulus location in visual fields does not effect electrical brain activity elicited by stereoscopic image significantly [5], but measured response in the present study largely depends on stimulus positions. It may reflect directional sensitivity of MEG measurement.

Statically displayed A-RDS elicited brain activity which was not seen in response to dynamic A-RDS was observed. It may be related to a steady-state stimulus of binocular rivalry.

On the other hand, the properties of accommodation and vergence vary subject by subject. It may effect latencies of brain activity related to depth perception

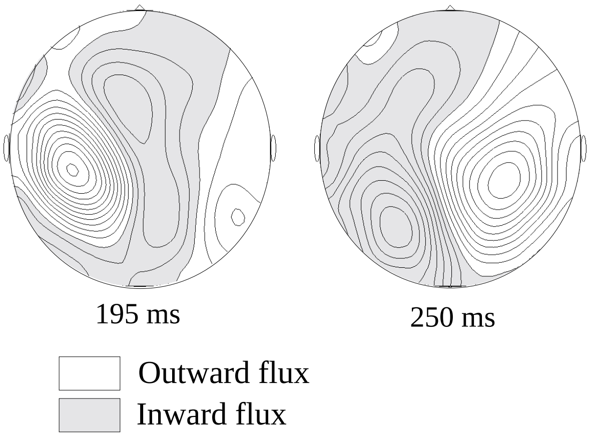

Figure 4: *The isocontour maps of the response evoked by dynamic C-RDS in subject YO at the latency of 195 ms and 250 ms. Three noisy channels were removed. The contour step was 18fT.*

and fluctuations in those latencies. Moreover, accommodation itself elicits some brain activity [6]. Therefore the process of focusing images on retinae should also be considered.

References

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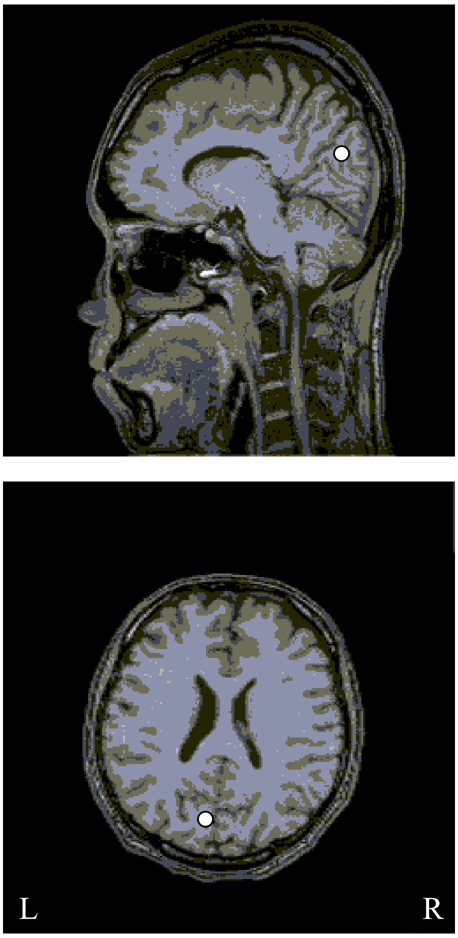

Figure 5: *Source localization of the response indicated right side of Figure 4. The goodness of fit was 88%.*

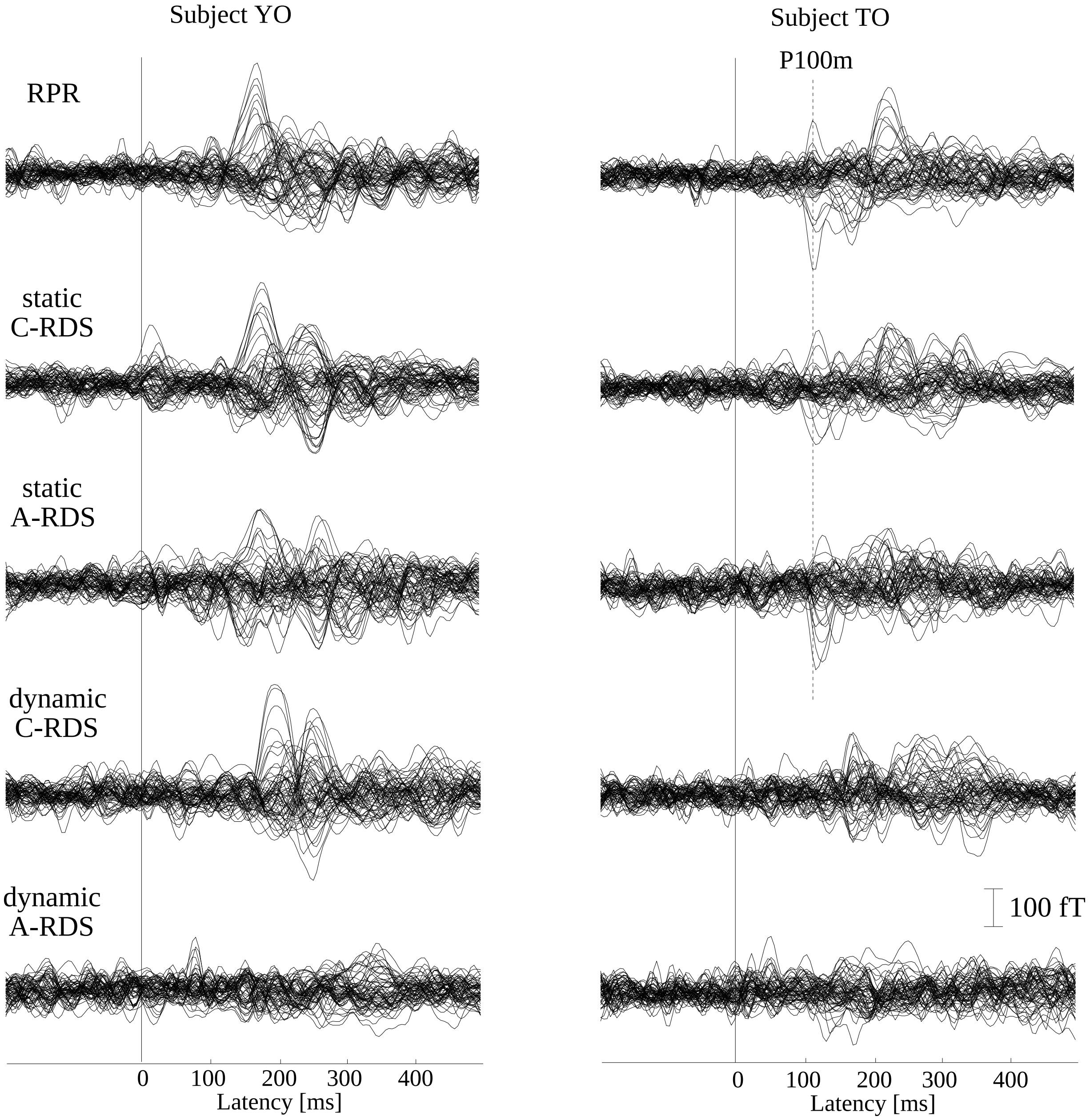

Figure 6: *The waveforms recorded at sensor channels of two subjects YO and TO in the experiment. Several noisy channels were removed. The right and the left side of the figure shows the result of subject YO and TO, respectively. The arrangement of 5 waveforms for an individual subject corresponds to RPR, static C-RDS, static A-RDS, dynamic C-RDS and dynamic A-RDS from the top to the bottom. Visual fields where stimuli were presented were upper right for YO and lower left for TO. Responses considered to be P100m are observed in responses to RPR, static C-RDS and static A-RDS in subject TO, but there are no obvious P100m in subject YO.*